Studies on the Shipworms I : The Occurrence and Seasonal Settlement of Shipworms.

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The Occurrence and Seasonal Settlement of Shipworms.

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Abstract——The previous investigation on the occurrence of shipworms in December, 1971 indicated the co-existence of three species of shipworms: *Bankia bipalmulata* LAMARCK, *Teredo navalis* LINNAEUS and *Lyrodus pedicellatus* QUATREFAGES. However, the absence of *B. bipalmulata* was found in this investigation carried out from February, 1971 to January, 1972. Of these three species, *T. navalis* was the commonest.

In this survey of larval settlement on floating wood surfaces, there was no settlement from January to May, and the first settlement of larvae was not observed until June, when water temperature was over 20°C. The explosive settlement was observed in September.

After June, boring damage always occurred when wood blocks were submerged in the sea for over 60 days.

Introduction

The import of logs into Japan has enormously increased in recent years, and this trend will continue for some time. The imported logs are transported by ship into 85 international trading ports along Japanese coasts. For the last three years the annual amount has been not less than 50,000,000 m^3, which is equivalent to more than 50 percent of Japan's total wood supply.

Prior to landing, these logs are generally stored in the sea water for classification, inspection and plant quarantine, and at least 10 to 20 days are required for these operations. Some of the logs are occasionally stored in the sea for over one month. During this period, these logs are vulnerable to the marine borers. Marine borers, including genus *Teredo* (shipworm), *Limnoria* (gribble), *Chelura* and *Martesia*,[1,2,3,4] are well known hazards to untreated wooden structures, wooden ships, and saw-logs along the coasts of Japan. If logs are stored for over two months in summer (July—October), marine borers invariably cause economic loss. Although the accurate estimation of loss is difficult, the annual loss, as well as the expense for protecting logs against marine borers, may be considerable.

In the case of sea water log storage area,[5,6,7] we must give attention to shipworms, whereas gribbles, *Chelura* and *Martesia* are not serious pests. Shipworms degrade logs even during short-term storage.

In 1969, a great loss was caused by shipworms in the sea water log storage area, Uchiura Port. Since the occurrence and breeding season of shipworms in the port were unknown, no counterplan was considered against marine borer damage.

At present, therefore, it is emphasized that the reasonable use of sea water log storage area, harbour hygiene, and protection methods are needed for preventing marine borer damage. So it is firstly desirable to survey the existing species and to determine the natural durability of various wood species in relation to the seasonal settlement of shipworm larvae. Difficulties in

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settling and boring of larvae vary with the properties of each wood species; hardness,[1,8,9] sapwood content[10] and toxicity of extractives, as well as the conditions of wood surfaces.[2]

In this survey, the seasonal settlement of shipworms, and boring damage to submerged rough-sawn timbers were examined. In addition, existing species of shipworms were identified.

Experimental

The testing site was the sea water log storage area, Otomi, Uchiura Port, situated in the southwestern part of Wakasa Bay in the Sea of Japan. Fig. 1 shows the locality of Uchiura Bay and the testing station in the storage area.

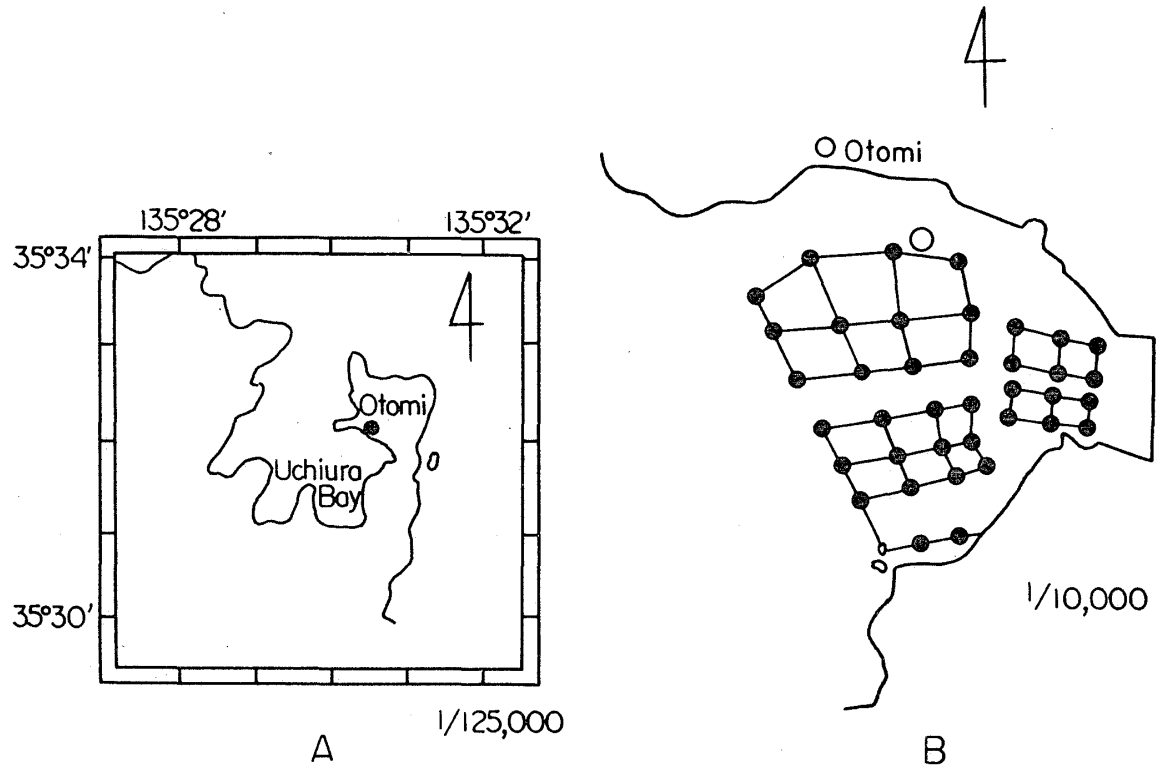


Fig. 1. A: Showing the geographic locality of Uchiura Bay and B: Log storage area showing testing station (a large open circle) and buoys (small black circle).

The wood species tested were as follows: Douglas fir (*Pseudotsuga menziesii* (MIRB.) FRANCO), Scotch pine (*Pinus sylvestris* LINNAEUS), western hemlock (*Tsuga heterophylla* SARGENT) and western red cedar (*Thuja plicata* D. DON). Many Scotch pine logs are imported from U.S.S.R. and the other three species of wood comprise most of the imported logs from North America.

Each wood test string consisted of twenty blocks, five each of four wood species. One test block was 10×10 (cm) in section and 50 cm in length with a center hole for rope penetration. These strings were fastened to the buoy, such that each block was half-submerged.

Testing strings were removed at regular intervals of 30 days. During from May to October, 1971, however, duplicate testing strings were submerged so as to compare the larval settlement for the same immersion period in different months.

After removal of the strings, mud, barnacles, and other surface debris were washed off the wood blocks. The blocks were then dried and planed, and the number of shipworm apertures on the underside surfaces of blocks, visible to the naked eye, was counted. After this count, four $4 \times 10 \times 0.2$-0.4 (cm) slices were cut at intervals of 10 cm from the end of each block for measuring the boring damage. The boring damage was defined as percent reduction in cross sectional area. The measuring device used was an automatic area meter, Hayashi Denko AMM-5 Type. The amount of limnorial attack was not assessed.

In addition, the surface water temperature was daily measured and the salinity and pH of sea water were occasionally measured.

These investigations were begun at February 1, 1971 and continued until January 28, 1972.

Results and Discussion

1. Existing species

Though it is well known that a pair of pallets is the most important key for identification of species, it is pointed out that the identification is not clear in some cases. The classification of the family *Teredinidae* is so complicated[11,12] that no attempt had ever been made to illustrate it on world-wide basis. Because no museum or marine laboratory collected standard specimens, *Teredinidae* nomenclature was in disorder. TURNER[13] has collected and identified many specimens from various parts of the world.

In this investigation, specimens were entrusted to her for identification of species. She distinguished two species: *Teredo navalis* LINNAEUS and *Lyrodus pedicellatus* QUATREFAGES (October, 1971).

The previous investigation on the occurrence of shipworms in December, 1970, however, indicated the co-existence of three species: *Bankia bipalmulata* LAMARCK, *Teredo navalis* and *Lyrodus pedicellatus*.* Of these species, *Teredo navalis* was by far the commonest. The absence of *Bankia bipalmulata* in this investigation is not surprising, since the existing species and their relative number are continuously affected by environmental factors, removal of infested timbers and introduction of new species.[14,15]

2. Water temperature, salinity and pH of sea water

The surface water temperature was measured daily. Table 1 shows the mean monthly water temperature from February, 1971 to January, 1972. Though the water temperature during a period from February to July, 1971 was higher than that in the same period of 1970, the maximum mean monthly temperature in August was lower by 1.4°C than that of 1970 (28.8°C). Hence, from September to December, lower temperature was observed than in 1970. In January, 1972, the water temperature was higher because of a warm winter.

Salinity was occasionally measured and averaged between 32 and 37 permill. pH was around

Table 1. The surface water temperature change.
(from Feb., 1971 to Jan., 1972)

Month	Feb. 1971	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1972
Water temperature (°C)	8.8	9.0	12.6	15.9	20.8	25.4	27.4	23.9	20.8	16.3	12.7	10.5

* Identification was entrusted to Dr. S. MAWATARI, Research Institute of Natural Resources, Tokyo, Japan.

8.0.

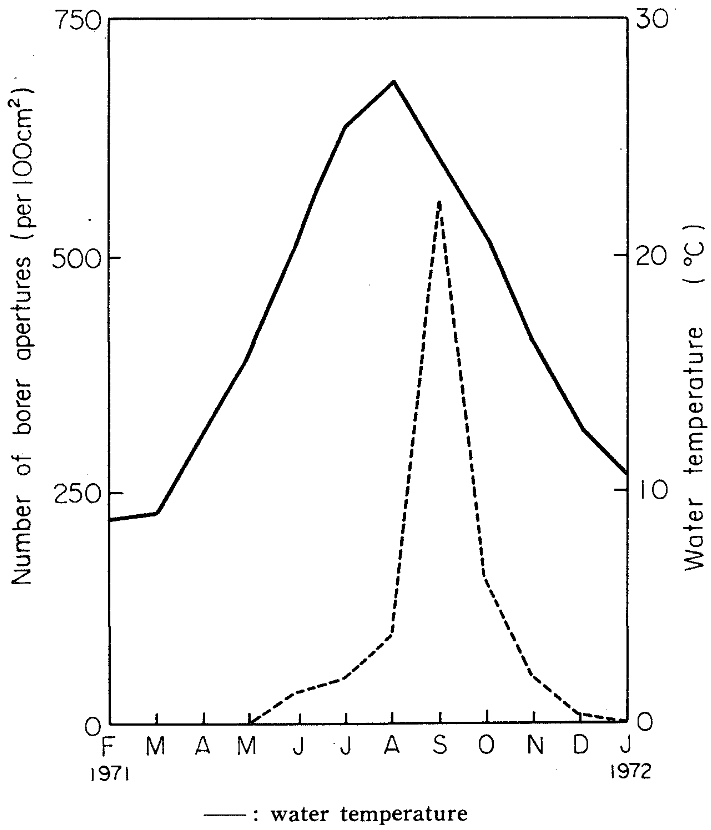
3. Breeding: Seasonal settlement of shipworm larvae

In this investigation, individual test strings consisting of twenty blocks each were fastened to the experimental buoy and positioned in floating condition. Counting the number of borer apertures, therefore, was carried out only on the bottom surfaces of each block. Table 2 shows

Table 2. Monthly settlement of shipworm larvae (number of borer apertures per 100 cm²).

Wood Species \ Month	Feb. 1971	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 1972
Douglas fir	0	0	0	0	17	19	87	707	144	18	0	0
Scotch pine	0	0	0	0	37	51	99	558	159	51	8	0
Western hemlock	0	0	0	0	32	37	108	483	194	31	2	0
Western red cedar	0	0	0	0	34	33	91	593	171	53	2	0

the monthly larval settlement on wood surfaces. In September, 1971, the explosive settlement of larvae occurred. It has been shown that the larvae, prior to settlement, spend 20 to 30 days in the free swimming stage.[16] Consequently, the larvae which settled on wood in September were released in August or early September. Hence, this remarkable settlement seems to have resulted from the advent of sexual maturity in shipworms which settled during



——: water temperature
- - -: number of borer apertures

Fig. 2. Relationship between larval settlement on test blocks of Scotch pine and water temperature.

June, July and August. Moreover, high water temperature in August might have stimulated the reproductive ability of shipworms. INO[17] mentioned that temperature impulse influenced the larval releasing activities of adult shipworms. The data in Table 2 assume that after Sep-

Table 3. Larval settlement on wood surfaces during a period from May to October, 1971.
(number of borer apertures per 100 cm²)
A : Douglas fir B : Scotch pine C : Western hemlock D : Western red cedar

A

		Removal Date					
		1 June	1 July	31 July	1 Sep.*	29 Sep.	29 Oct.
Immersion Date	2 May	0	14	44	138	414	436
	1 June		17	26	95	278	394
	1 July			19	125	352	394
	31 July				87	355	696
	1 Sep.*					707	1096
	29 Sep.						144

B

		Removal Date					
		1 June	1 July	31 July	1 Sep.*	29 Sep.	29 Oct.
Immersion Date	2 May	0	27	38	170	404	526
	1 June		37	44	131	325	432
	1 July			51	115	369	373
	31 July				99	428	536
	1 Sep.*					558	990
	29 Sep.						159

C

		Removal Date					
		1 June	1 July	31 July	1 Sep.*	29 Sep.	29 Oct.
Immersion Date	2 May	0	24	42	91	284	329
	1 June		32	40	105	458	592
	1 July			37	144	352	440
	31 July				108	471	534
	1 Sep.*					483	959
	29 Sep.						194

D

		Removal Date					
		1 June	1 July	31 July	1 Sep.*	29 Sep.	29 Oct.
Immersion Date	2 May	0	23	28	164	513	580
	1 June		34	59	132	340	473
	1 July			33	141	347	302
	31 July				91	453	459
	1 Sep.*					593	1112
	29 Sep.						171

* Two days late under stormy weather.

tember, when water temperature fell continuously, the decline of sexual activities agreed with the decrease of larval settlement. There was no attack from January to May, and the first settlement of larvae was not observed until June, when water temperature was over 20°C.

Statistical analysis revealed no variation among the four wood species.

The relationship between the larval settlement on Scotch pine wood blocks and water temperature is shown in Fig. 2.

Table 3 shows the larval settlement of duplicate test blocks during a period from May to October. Longer immersion resulted in increased settlement of larvae on wood surfaces with the exception of one case in western red cedar. However, high infestation discouraged further settlement of larvae on wood surfaces. This is probably due to the decrease of acceptable surface to be settled by shipworm larvae. The fouling organisms, such as barnacles, covered the surfaces of wood blocks and deterred attachment and settlement of larvae. In the case of wood blocks submerged on September 1, however, enormous settlement occurred during October. This is probably accounted for by selective settlement of larvae necessiated by the barnacle cover. Also, Douglas fir blocks submerged on July 31 exhibited high settlement in October. At this point, it is necessary to consider how immersion period effected larval acceptability of various wood species, and which wood species had high resistance to fouling organisms.

4. Boring damage

Up to now, the number of shipworm tunnels[7] and weight[8] or area reduction[10] have been used as the index of boring damage. Of these criteria, area reduction seems to be the best if measurement can be done easily and accurately. In this investigation, the area reduction was measured using an automatic area meter, accurate to the nearest square millimeter.

The results are summarized in Table 4. Western hemlock was the most heavily broken,

Table 4. Boring damage : percentage of area reduction.
A : Douglas fir B : Scotch pine C : Western hemlock D : Western red cedar

A

		Removal Date					
		1 June	1 July	31 July	1 Sep.*	29 Sep.	29 Oct.
Immersion Date	2 May	0	0	0-5	5-10	5-20	5-20
	1 June		0	0-1	5-10	10-20	10-20
	1 July			0	0- 1	5-15	10-15
	31 July				0	0- 1	5-10
	1 Sep.*					0	0- 5
	29 Sep.						0

B

		Removal Date					
		1 June	1 July	31 July	1 Sep.*	29 Sep.	29 Oct.
Immersion Date	2 May	0	0	0-5	5-20	10-20	15-25
	1 June		0	0-5	5-10	15-25	15-30
	1 July			0	5-10	15-25	15-25
	31 July				0	0- 5	10-25
	1 Sep.*					0	5-15
	29 Sep.						0- 1

C

	Removal Date					
Immersion Date	1 June	1 July	31 July	1 Sep.*	29 Sep.	29 Oct.
2 May	0	0	0-5	5-20	10-25	20-25
1 June		0	0-5	10-25	25-35	30-45
1 July			0	0- 5	20-30	25-45
31 July				0- 1	5-15	15-30
1 Sep.*					0- 1	10-25
29 Sep.						0- 1

D

	Removal Date					
Immersion Date	1 June	1 July	31 July	1 Sep.*	29 Sep.	29 Oct.
2 May	0	0	0-1	5-15	10-20	5-15
1 June		0	0-5	5-20	5-20	15-25
1 July			0	0- 5	5-15	10-25
31 July				0	0- 5	5-15
1 Sep.*					0	5-10
29 Sep.						0

* Two days late under stormy weather.

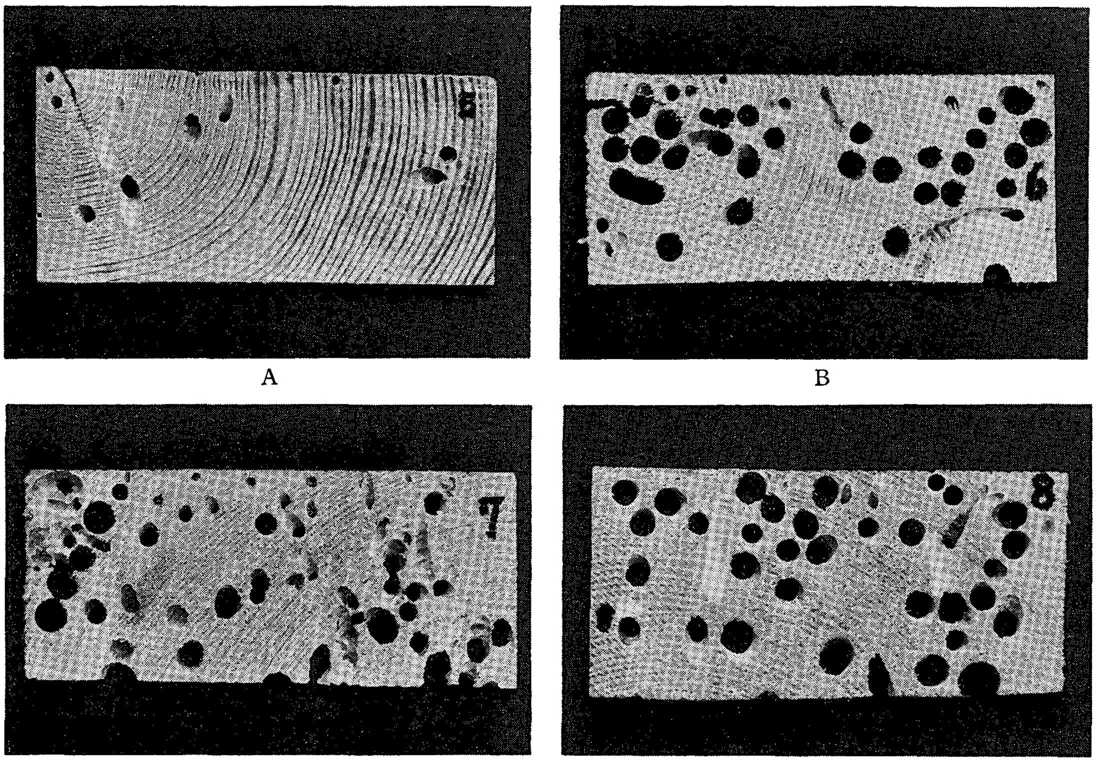


Fig. 3. Wood slices used for measuring the boring damage (Scoth pine).
Immersion period
A : 2 May-31 July, 1971 B : 2 May- 1 Sep., 1971
C : 2 May-29 Sep., 1971 D : 2 May-29 Oct., 1971

and followed by Scotch pine, western red cedar and Douglas fir. Although western red cedar is the lightest among the four wood species, it was more durable. This is probably due to high toxicity of extractives. It has been shown that[18~21] timbers having densities over 0.9 g/cm^3 are perfectly or nearly free from borer attack for short-term immersion.

After June, damage always occurred when wood blocks were submerged for over 60 days. In the case of 60 or 90 day immersion periods including September, the damage was greater than that during the same period of other months. It is clear that this result depended on the remarkable larval settlement in September. From the data on larval settlement (Table 3), however, the damage was unexpectedly small. This means that some of larvae died just after settlement and that high population density prevented normal growth. This suggests the necessity of studying not only on the relationship between the number of larval settlements and survival rate, but also the relationship between population density and growth rate. Fig. 3 shows wood slices used for measuring the boring damage.

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